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HOW I DO IT - TUMOR - SCHWANNOMA

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Hearing preservation in vestibular schwannoma surgery via retrosigmoid transmeatal approach

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Abstract

Background Advances in various diagnostic and/or treatment modalities, including radiological imaging, neuromonitoring, and microsurgical techniques, have resulted in treatments of vestibular schwannomas being aimed at preserving facial and hearing functions while achieving optimal tumor control.

Method We describe our surgical technique for hearing preservation in vestibular schwannoma surgery.

Conclusion The retrosigmoid transmeatal approach under continuous neuromonitoring (auditory brainstem response, cochlear nerve action potentials, and continuous facial nerve monitoring) enables gross-total resection of vestibular schwannomas, while preserving hearing and facial functions. Radiological assessment and microsurgical techniques, such as meticulous tumor dissection, are also essential for functional preservation with sufficient tumor removal.

Keywords Acoustic neuroma · Cerebellopontine angle tumor · Internal acoustic meatus · Lateral suboccipital approach · Neuromonitoring · Skull base surgery

Abbreviations

ABR	Auditory brainstem response
CN	Cranial nerve
CNAP	Cochlear nerve action potentials
CT	Computed tomography
MRI	Magnetic resonance imaging
SEP	Somatosensory evoked potential

Relevant surgical anatomy

Cranial nerves (CNs) VII and VIII cross the cerebellopontine angle from the pontomedullary junction to the internal acoustic meatus, whereas CN VII courses ventral to CN VIII (Fig. 1). Junctions between CNs VII/VIII and the brainstem are located ventral to the flocculus and choroid plexus. At the lateral end of the meatus, the facial and superior vestibular nerves are above the transverse crest while the facial nerve anterior, and the cochlear and inferior vestibular nerves course below while the cochlear nerve anterior. The vertical crest or "Bill's bar" is located between the facial and superior vestibular nerves. Thus, the facial nerve runs anterosuperiorly, the cochlear nerve anteroinferiorly, the superior vestibular nerve posterosuperiorly, and the inferior vestibular nerve posteroinferiorly.

Description of the technique

Setup and craniotomy

After setting up the neuromonitorings, including monitors for auditory brainstem response (ABR), cochlear nerve action potentials (CNAP), somatosensory evoked potential (SEP), and evoked facial electromyograms, the patient is placed in the park-bench position (Fig. 2). We make a retroangular-shaped postauricular incision and a retrosigmoid craniotomy (Fig. 2b). The posterior half of the sigmoid sinus should be exposed suf-

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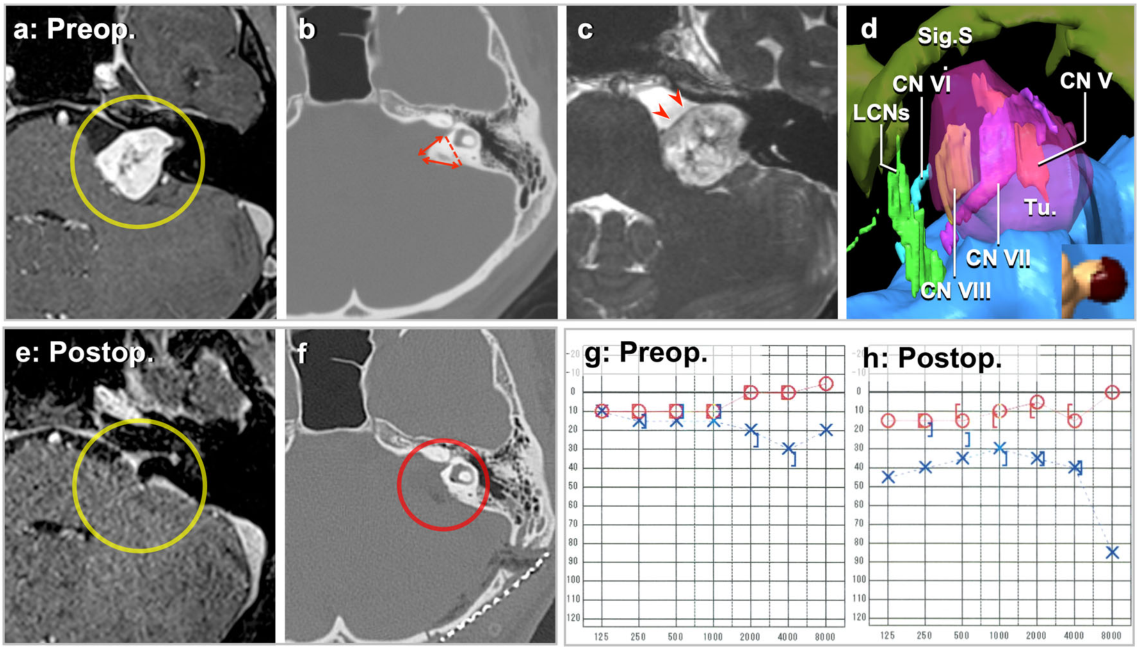

Fig. 1 Radiological images. **a** Preoperative MRI displayed a cerebellopontine angle tumor extending into the internal acoustic meatus. **b** The internal acoustic meatus was enlarged. Preoperative measurements for drilling are indicated with red arrows. **c**, **d** The facial nerve was predicted to be displaced dorsally (**c**, red arrow heads). **e** The vestibular schwannoma was completely resected through the retrosigmoid transmeatal approach. **f** The posterior wall of the acoustic meatus was drilled out while preserving the vestibule and semicircular canals. **g**, **h** The pre- and postoperative audiograms show the preservation of hearing function. CN, cranial nerve; L, lower; Preop., preoperative; Postop., postoperative; S., sinus; Sig., sigmoid; Tu., tumor

ficiently to obtain an adequate operative field and lighting while minimizing cerebellar retraction. After making a U-shaped dural incision, the incised dura is flipped over the sigmoid sinus and the sinus is pulled anteriorly for wider access into the cerebellopontine angle [7].

Tumor exposure

After releasing the cerebrospinal fluid in the cerebellomedullary cistern, the lower CNs and choroid plexus are dissected from the caudal margin of the tumor. Firstly, an arachnoid fold (double layers of arachnoid membrane on the tumor) is moved toward the brainstem to expose the cisternal part of the tumor (Fig. 3a) [2]. We routinely check direct facial nerve stimulation over the dorsal tumor surface, as a dorsally displaced facial nerve is rarely encountered [5, 6].

Continuous facial nerve monitoring and CNAP

After identifying the junctions of CNs VII and VIII from the brainstem, ball-type electrodes are placed on proximal parts of CNs VII and VIII, to start the continuous facial nerve monitoring and CNAP, respectively (Fig. 3b). However, in cases of large tumors hiding proximal CNs VII and VIII, tumor

Fig. 2 Operative setting. **a** We routinely monitor ABR, SEP, and electromyograms of CNs V and VII. **b** A retroangular-shaped postauricular incision was designed to expose the edge of the transverse and sigmoid sinuses. **c**, **d** The patient was put in the park-bench position. Front., frontalis; M., muscle; Mass., masseter; Orb., orbicularis

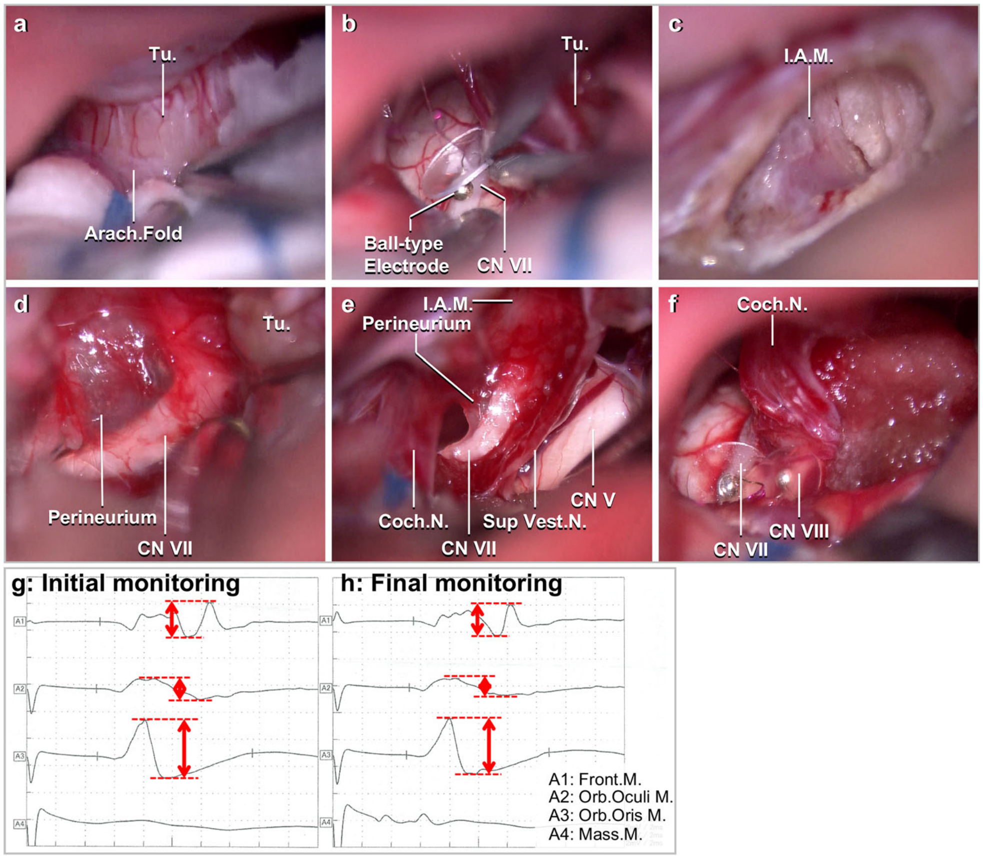

Fig. 3 Intraoperative photographs. **a** After access into the cerebellopontine angle, the arachnoid fold (double layers of arachnoid membrane on the tumor) was moved toward the brainstem to expose the tumor. **b** After identifying the root exit zone of CN VII, a ball-type monopolar stimulating electrode was placed on proximal CN VII to start the continuous facial nerve monitoring. **c** Transmeatal drilling exposed the intrameatal tumor under the dura lining the meatus. **d** CN VII behind the perineurium of the vestibular nerve was observed during tumor dissection. **e** The facial, cochlear, and superior vestibular nerves were preserved anatomically after gross-total tumor removal. **f** The preserved cochlear nerve and a ball-type electrode placed on its proximal part were seen. **g**, **h** Evoked facial electromyograms were monitored continuously and preserved throughout tumor removal. Arach., arachnoid; CN, cranial nerve; Coch., cochlear; Front., frontalis; I.A.M., internal acoustic meatus; M., muscle; Mass., masseter; N., nerve; Orb., orbicularis; Sup., superior; Tu., tumor; Vest., vestibular

debulking is firstly performed from its caudal part to create a space to place the electrodes. Evoked facial electromyograms are monitored at a frequency of 1 Hz throughout tumor removal, to continually assess the real-time neural condition without interrupting the microsurgical procedure (Fig. 3g) [1]. The direct recording of CNAP, which provides rapid response of the cochlear nerve status, is watched closely in combination with ABR, for continuous and stable assessment of hearing function (Fig. 4).

Opening of the internal acoustic meatus

After sufficient debulking of the cisternal part of the tumor, the posterior wall of the internal acoustic meatus is drilled without injuring the vestibule and the posterior semicircular canal (Fig. 3c). Drilling area is routinely measured on preoperative CT scans, since it varies in each case by nonpathological variation and pathological destruction (Fig. 1b). Heat injury should be avoided with sufficient irrigation during the drilling [10]. We always take care of minimal cerebellar retraction without using the spatula, especially in hearing preservation surgery. In cases in which a high jugular bulb disturbs exposure of the meatus, the roof of the bulb is exposed and compressed caudally with bone wax to achieve a sufficient surgical field [9]. At the initial stage of intrameatal tumor dissection, electrically activated dissectors are utilized for prompt facial nerve identification without damaging it in the narrow surgical field inside the meatus [4].

Nerve dissection and tumor removal

With the subperineurial or subcapsular dissection using forceps and dissectors, the entire tumor is separated from the facial and cochlear nerves in a semi-sharp fashion (Fig. 3d) [5, 8].

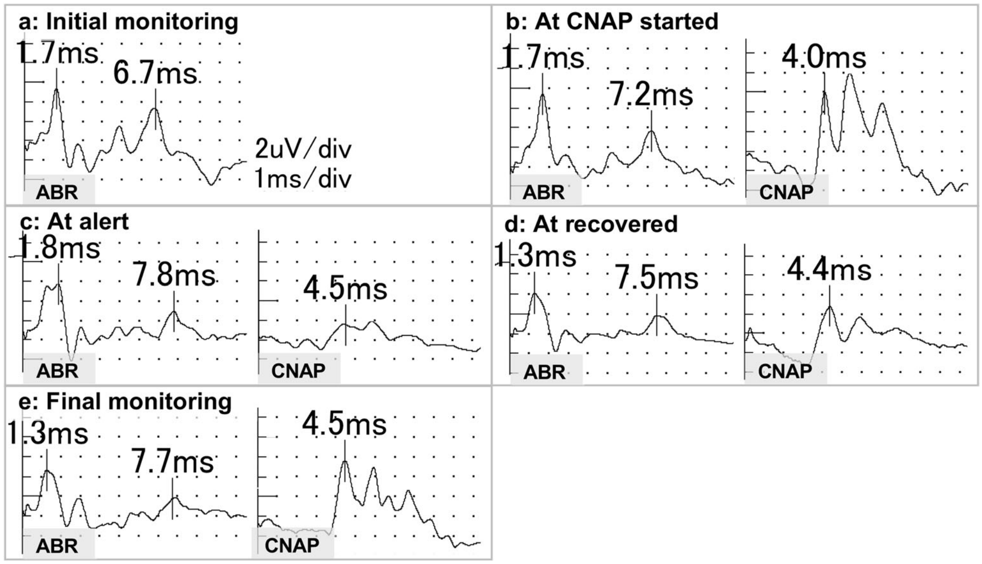

Fig. 4 Intraoperative ABR and CNAP. **a**, **b** ABR was monitored throughout the surgery, and CNAP was started when an electrode was placed during the initial step of the microsurgery. **c**, **d** CNAP's large amplitude showed its decrease clearly during the dissection, and soon later, ABR alerted likewise. We stopped the microsurgical manipulation, and both monitorings recovered in a few minutes. **e** Preservation of ABR and CNAP predicted hearing preservation after tumor removal.

Continuous facial nerve monitoring, ABR, and CNAP should be watched closely throughout the microsurgical procedure, and when there is an alert, manipulation is stopped until recovery (Fig. 4c, d). It is sometimes said that intrameatal tumor dissection should be in the medial to lateral direction, but we believe that lateral to medial dissection under these real-time monitorings is mandatory and has no disadvantages [5]. We always aim to resect as much of the intrameatal tumor as possible, because residual tumor inside the meatus can lead to a high recurrence rate. In the presented case, the gross-total resection was performed, while anatomically preserving the facial, cochlear, and superior vestibular nerves (Fig. 3e, f). As predicted by intraoperative continuous neuromonitorings, the patient did not have any facial or hearing deficit after the surgery (Figs. h, 3h, and 4e).

Indications

Patients with preoperative hearing categorized as class A and B according to the American Academy of Otolaryngology-Head and Neck Surgery (AAO-HNS) classification are the main candidates for hearing preservation surgery. However, even patients in class D experienced postoperative hearing improvement [3], so we always try to preserve the cochlear nerve anatomically under monitoring of ABR with a standby of CNAP.

Limitations

Intraoperative ABR is often detected reliably even in cases with undetectable preoperative ABR, but hearing preservation is significantly difficult when intraoperative ABR is not clearly identified. In some cases, even with detectable intraoperative ABR, the ABR is too fragile to preserve throughout tumor removal. This fragileness cannot yet be perfectly predicted before attempting hearing preservation surgery, so the surgical aim should be carefully considered in each case with precise informed consent. The balance of maximum tumor removal and functional preservation should be considered based on neuromonitoring in addition to tumors' solidity and vascularity, during the surgery. Follow-up examinations must be performed carefully, particularly in cases in which a thin film of the tumor adhering to the nerves is left for functional preservation.

How to avoid complications

Based on our experience of more than 150 cases with successful useful hearing preservation, continuous intraoperative neuromonitoring of facial and cochlear nerves is essential for functional preservation. Sufficient craniotomy and elevation of the sigmoid sinus can minimize cerebellar retraction and excessive tension on CNs. Heat injury should be avoided by sufficient irrigation during the drilling and minimal bipolar coagulation around CNs. To prevent cerebrospinal fluid leakage, the dura is closed water-tightly under a microscope, with confirmation by the Valsalva maneuver. In most cases, autologous graft patch nor a postoperative lumbar drainage is not necessary.

Specific perioperative considerations

Owing to its recent advancements, we recommend radiosurgery for the elderly patients with small- to medium-sized tumors. For patients with neurofibromatosis type 2, leaving residual tumors for giving priority to functional preservation should be carefully considered, as significant tumor regrowth has been encountered in some of these patients.

Specific information for the patient

Patients should be informed about alternative treatment choices for this benign tumor, general surgical risks, and specific risks as mentioned above, including hearing and facial deficits and cerebrospinal fluid leakage.

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Compliance with ethical standards

Informed consent Informed consent was obtained from a participant included in this study.

Conflict of interest The authors declare that they have no conflict of interest.

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Key Points

- Sufficient craniotomy and dural opening for minimizing cerebellar retraction
- Combination of ABR and CNAP for continuous and stable hearing assessment
- Early start of and careful observation of continuous facial nerve monitoring
- Safe transmeatal drilling with sufficient irrigation
- Electrically activated dissectors for safe and prompt facial nerve identification inside the internal acoustic meatus
- Subperineurial tumor dissection in a semi-sharp fashion
- Maximum resection of the intrameatal tumor to prevent later recurrence
- Intraoperative decision-making for a balance between maximum tumor resection and functional preservation based on neuromonitoring
- Microscopic dural closure to prevent postoperative cerebrospinal fluid leakage
- Careful follow-up examination, particularly in cases with intentional near-total removal for functional preservation